

# Laser-Directed CVD 3D Printing System for Refractory Metal Propulsion Hardware, Phase II

Completed Technology Project (2015 - 2021)

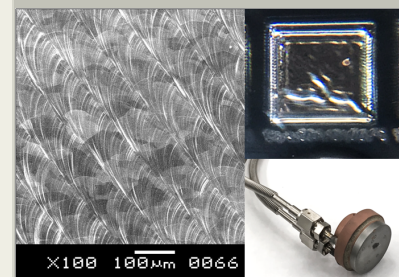


## Project Introduction

In this work, Ultramet is developing a three-dimensional (3D) laser-directed chemical vapor deposition (CVD) additive manufacturing system to build free-form refractory metal components for liquid rocket propulsion systems. By combining Ultramet's experience in refractory metal fabrication by CVD with computer control of directed laser energy, nearly unlimited expression of part shape and metal composition can be realized for component fabrication. 3D additive manufacturing is revolutionizing many industries by offering unconstrained complex build geometries and reduced cost, lead time, and material usage compared with conventional manufacturing techniques. By developing laser-directed CVD technology for refractory metals, Ultramet will bring these inherent benefits to a class of materials that are notoriously difficult to form and thus are expensive to implement. By depositing successive layers of metal directly from reactive precursor gases, the system will be able to build components from rhenium, tungsten, tantalum, niobium, and their alloys with complex internal features and reduced assembly part count. In Phase I, Ultramet designed and built a laser-directed CVD reactor, successfully deposited both rhenium and tungsten in a controlled fashion, and achieved well-defined two-dimensional spatial control and layering as a strong demonstration of process feasibility. In Phase II, Ultramet will design and build a new high-power, high-speed reactor with optical z-axis control to enable layering for 3D geometries at high deposition rates. Software and hardware integration will provide automated layering control to enable fully automatic additive manufacturing from 3D models. The deposited rhenium and its layering will be characterized and optimized by direct printing of mechanical test specimens and small demonstrator articles. This phase of the research will mature the system and technology to a level where automated fabrication of small 3D components is possible.

## Anticipated Benefits

The proposed manufacturing technology has the potential to revolutionize the fabrication of engine and hot gas path components for liquid and solid rocket propulsion. By providing the capability to build free-form parts in refractory metals, systems engineers and designers will be free to pursue optimized designs for increased performance and reduced weight while simultaneously reducing the manufacturing constraints, cost, and lead time associated with such hardware. The technology will be directly applicable to the fabrication of prototype and production propulsion components. The proposed manufacturing technology will be directly applicable to the fabrication of propulsion components for attitude control and apogee engines for commercial and government satellites and for solid and liquid divert and attitude control systems for kinetic kill vehicles. In addition, the large refractory metal crucible market would benefit from the tailorable design control to maximize value in the development of semiconductor foundries. Refractory metals are also of great importance in nuclear fission and fusion power plant systems, where



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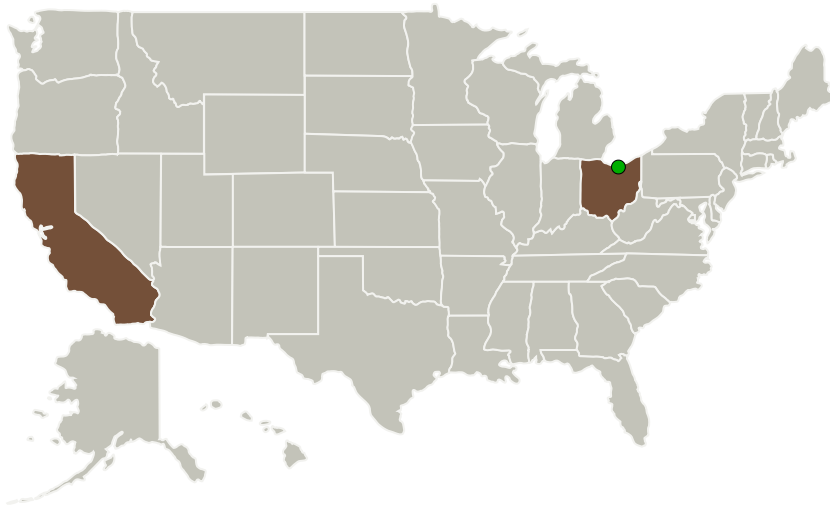
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they are often the only suitable material but suffer from fabricability limitations that would be effectively lifted by the successful realization of this technology. Tungsten components for the fusion research community and future power plants represent a specific significant potential market.

## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Ultramet	Lead Organization	Industry	Pacoima, California
● Glenn Research Center(GRC)	Supporting Organization	NASA Center	Cleveland, Ohio

### Primary U.S. Work Locations

California	Ohio
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## Project Transitions

**May 2015:** Project Start

## Organizational Responsibility

### Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

### Lead Organization:

Ultramet

### Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

## Project Management

### Program Director:

Jason L Kessler

### Program Manager:

Carlos Torrez

### Project Managers:

David L Ellis  
Matthew C Deans

### Principal Investigator:

James G Selin

### Co-Investigator:

James Selin

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✓ **September 2020:** Closed out

## Closeout Documentation:

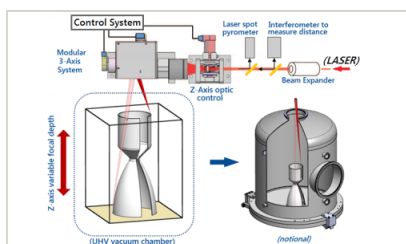
- Final Summary Chart(<https://techport.nasa.gov/file/138245>)

✓ **May 2021:** Closed out

## Closeout Documentation:

- Final Summary Chart PDF(<https://techport.nasa.gov/file/138244>)

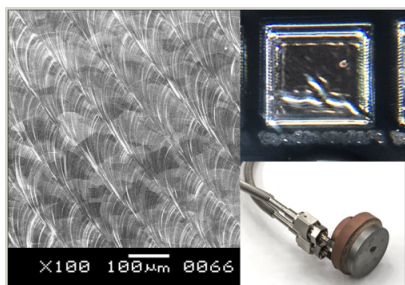
## Images



### Briefing Chart

Laser-Directed CVD 3D Printing System for Refractory Metal Propulsion Hardware, Phase II Briefing Chart

(<https://techport.nasa.gov/image/136599>)

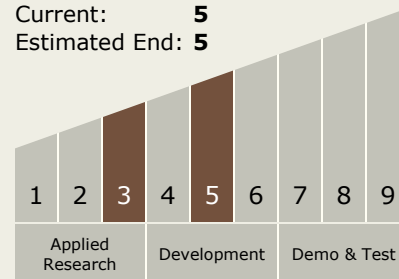


### Final Summary Chart Image

Laser-Directed CVD 3D Printing System for Refractory Metal Propulsion Hardware, Phase II (<https://techport.nasa.gov/image/136815>)

## Technology Maturity (TRL)

Start: **3**  
Current: **5**  
Estimated End: **5**



## Target Destinations

The Moon, Mars, Outside the Solar System, The Sun, Earth, Others Inside the Solar System